

A comparative study of root canal preparation using ProFile .04 and Lightspeed rotary Ni-Ti instruments

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Abstract

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Aim The purpose of this study was to compare several parameters of root canal preparation using two different rotary nickel–titanium instruments: ProFile .04 (Dentsply/Maillefer, Ballaigues, Switzerland) and Lightspeed (Lightspeed Technology Inc., San Antonio, TX, USA).

Methodology Fifty extracted mandibular molars with root canal curvatures between 20° and 40° were divided into two similar groups having equal mean curvatures. The teeth were then embedded into a muffle system as described by Bramante *et al.* (1987) and modified by Hülsmann *et al.* (1999b). All root canals were prepared using ProFile .04 or Lightspeed Ni-Ti instruments to size 45 following the manufacturers' instructions. The Lightspeed system was used in a step-back technique; ProFile .04 instruments were used in a crown-down technique. The following parameters were evaluated: straightening of curved root canals (superimposition of pre- and postoperative radiographs), postoperative root canal diameter (superimposition of pre- and postoperative photographs of root canal cross-sections), safety issues (file fractures, perforations, apical blockages, loss of working length) (protocol), cleaning ability (SEM-evaluation of root canal walls using a five-score system for debris and smear layer), and working time (protocol).

Statistical analysis was performed using the Wilcoxon test ($P < 0.05$) for straightening, and Fisher's exact-test ($P < 0.05$) for comparison of cross-sections, for comparison of contact between pre- and postoperative diameter, root canal cleanliness and working time.

Results Both Ni-Ti systems maintained curvature well; the mean degree of straightening was less than 1°

for both ProFile .04 and for Lightspeed with no statistical significance between the groups. Most procedural incidents occurred with Profile .04 instruments (three fractures), Lightspeed preparation was completed without instrument fractures. Loss of working length, perforations or apical blockage did not occur with either instrument. Following preparation with Profile .04, 64.0% of the root canals had a round, 30.7% an oval, and 5.3% an irregular cross-section, Lightspeed preparation resulted in a round cross-section in 41.3% of cases, an oval shape in 45.3% of cases; 13.3% of cases had an irregular cross-section. No significant differences were found between the two systems. Lightspeed instruments enlarged the root canal more uniformly with no specimen showing 50% or more contact between pre- and postoperative diameter. The difference was statistically significant only for the coronal third of the root canals ($P = 0.032$). Mean working time was significantly shorter for Profile .04 (105 s) than for Lightspeed (140 s) ($P = 0.026$). For debris removal Lightspeed achieved the best results (68% scores 1 and 2), followed by Profile .04 (48.4%) with no significant differences between the systems. The results for remaining smear layer were similar: the lowest amount of smear layer on the root canal walls was found after preparation with Lightspeed (30.7% scores 1 and 2), followed by Profile .04 (23.1%). In the coronal third of the root canals Lightspeed performed significantly better than Profile .04 ($P = 0.029$); in the middle and apical third the differences were not significant.

Conclusions Both systems under investigation respected original root canal curvature and were safe to use. Both systems can be recommended for clinical use.

Keywords: automated root canal preparation, Lightspeed, Ni-Ti instruments, ProFile .04.

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Introduction

The main parameters included in the evaluation of any technique or device for root canal preparation should be the ability to clean the root canal walls and to shape the root canal without straightening. In addition, a prerequisite for the use of any instrument or technique is that it is safe. It has been shown in numerous investigations that preparation of curved root canals with stainless steel instruments frequently results in undesirable aberrations such as elbows, zips and danger zones, as well as loss of working length, perforations or instrument fractures (Weine *et al.* 1975, 1976, Abou-Rass *et al.* 1980, Bolanos *et al.* 1988, Al-Omari *et al.* 1992a,b, Hülsmann & Stryga 1993, Hülsmann *et al.* 1998, 1999a, Hülsmann 2000). Many studies have also reported that large amounts of debris and smear layer often remain after manual or automated preparation with endodontic handpieces (Hülsmann & Stryga 1993, Hülsmann *et al.* 1998, 1999a, Hülsmann 2000).

During the last decade, several new nickel–titanium instruments for manual root canal preparation as well as for use in a rotary endodontic handpiece have been developed in order to facilitate the difficult and time consuming process of cleaning and shaping the root canal system and to improve the final quality of root canal preparation.

In the past few years advanced instrument designs including non-cutting tips, radial lands and varying tapers have been developed to improve the safety of preparation, to shorten working time, and to create a greater flare of preparations. Due to these new instrument designs, advanced preparation concepts have been developed: most Ni–Ti systems with increased instrument tapers are used in a crown-down sequence.

Numerous studies have shown the ability of several new rotary nickel–titanium systems to maintain original canal curvature and to produce a well tapered root canal form sufficient for obturation. Nevertheless, serious concern has been expressed about the safety of such systems, largely because of the high incidence of instrument fractures (Kavanagh & Lumley 1998, Barthel *et al.* 1998, Schäfer & Fritzenschaft 1999, Baumann & Roth 1999).

Few studies have been published investigating the cleaning ability of these new rotary nickel–titanium files (Peters *et al.* 1997, Peters *et al.* 1998, Kochis *et al.* 1998, Bertrand *et al.* 1999, Medioni *et al.* 1999, Hülsmann *et al.* 2001).

The aim of the present study was to evaluate several parameters of automated root canal preparation using

Profile .04 (Dentsply Maillefer, Ballaigues, Switzerland) and Lightspeed (Lightspeed Inc., San Antonio, TX, USA) Ni–Ti instruments. The parameters evaluated were: straightening of curved root canals, postoperative root canal diameter, root canal cleanliness, incidence of procedural errors such as file fractures and perforations, loss of working length, and working time.

Materials and methods

Preparation of teeth

A modification of the Bramante technique (Bramante *et al.* 1987, Hülsmann *et al.* 1999b) was used to evaluate simultaneously the cleaning ability as well as preparation form (longitudinal and cross-sectional), safety issues, and working time on extracted teeth under conditions comparable to the clinical situation. A muffle-block was constructed, consisting of a u-formed middle section and two lateral walls which are fixed together with three screws. Grooves in the walls of the muffle-block allowed removal and exact repositioning of the complete tooth-block or sectioned parts of the tooth. A modification of a radiographic platform, as described by Southard *et al.* (1987) and Sydney *et al.* (1991) could be adjusted to the outsides of the middle part of the muffle. This allowed the exposure of radiographs under standardized conditions and geometric relationship in order to allow the superimposition of views taken before, during and after root canal preparation. Two metallic reference objects inserted into the film holder facilitated exact superimposition of the radiographs. The system and the evaluation technique have been described previously (Hülsmann *et al.* 1999b).

Fifty extracted mandibular molars with two curved mesial root canals were opened and controlled for apical patency with a size 10 reamer. All teeth were shortened to a length of 19 mm. The teeth were mounted in the mould with acrylic resin and isolated with rubber dam and a clamp, simulating the clinical situation and ensuring the operator could gain access to the root canal only from the mesial direction. Root canal curvatures were measured as described by Schneider (1971) from preoperative radiographs after insertion of a size 15 reamer. The teeth were randomly divided into two groups. By exchanging a few single teeth a similar mean degree of curvature was achieved for both groups. Twenty-five teeth with 50 curved mesial root canals were prepared with the Profile .04 Ni–Ti system (Dentsply Maillefer), and 25 teeth were prepared with Lightspeed Ni–Ti rotary instruments (Lightspeed Inc.).

Instruments and preparation techniques

Profile .04

In the present study root canal preparation was performed in the following crown-down-sequence: Profile .04 size 25: 14 mm, size 30: 14 mm, size 20: 16 mm, size 15: working length (18 mm), sizes 20–45: working length (18 mm). The total number of instruments used was 10.

Lightspeed

Preparation with Lightspeed instruments was performed using a step-back technique (Wildev & Senia 1989, Wildev *et al.* 1992). The sequence of instruments used in the present study was the one proposed by the manufacturer: Hand instrument size 15: working length (18 mm), Lightspeed instruments sizes 20–45: working length (18 mm), sizes 47–70: step-back with each instrument used 1 mm shorter than the preceding one. The total number of instruments (incl. size 15 hand-file) used was 20.

All root canals were prepared with a dental handpiece in a low-speed motor with torque-control (TCM 3000, Nouvag, Konstanz, Germany). Preparation speed was 350 r.p.m. for Profile .04 and 1300 r.p.m. for Lightspeed. Irrigation was performed with 2 mL NaOCl (3%) after each instrument size in the ProFile group and after each second instrument in the Lightspeed group with a final irrigation of 5 mL NaOCl (3%) in both groups. RC-Prep (Premier, Philadelphia, USA) was used as a chelating agent with each instrument. In both groups instruments were discarded after preparation of 10 root canals.

Assessment of preparation

First the mesio-buccal root canal was instrumented in the unsectioned teeth. Maintenance of root canal curvature, safety issues (loss of working length, apical blockage, instrument fracture, lateral perforation), and working time were evaluated at this time. Before preparation a radiograph with a size 15 stainless steel reamer *in situ* was taken and the initial root canal curvature was determined using the technique proposed by Schneider (1971). Following preparation to size 45 a further radiograph was taken with a size 40 stainless steel reamer. The outlines of the inserted instruments, the root outlines and the metallic reference objects in the film holder were superimposed under an X-ray viewer with a 10× magnification and the degree of straightening was evaluated by

measuring the angle between the two instrument tips. The reference objects allowed control of exact superimposition of the radiographs.

The teeth were sectioned horizontally at 3, 6 and 9 mm from the apex and the preoperative root canal diameters were photographed under standardized conditions. The horizontal segments were remounted into the mould which was facilitated by the horizontal grooves and the mesio-lingual root canals were prepared to size 45 as described above. Again procedural accidents were recorded and straightening of the root canal curvature was measured using the radiographic platform. At the end of preparation the cross-section of the disto-lingual root canal was photographed again. According to Loushine *et al.* (1989) the postoperative cross-sections were classified as round, oval or irregular using reference photographs. Only irregular cross sections were regarded as unacceptable preparation results, since an oval cross section may be due to the cutting angle during the sectioning procedure. The divergence of pre- and postoperative root canal diameter was evaluated by superimposing pre- and postoperative canal outlines.

Following this the segments were removed from the mould and the three root segments were freed from the resin and split vertically. For the SEM investigation the mesio-buccal root canals, prepared before sectioning the teeth, were selected since irregular hydrodynamics in the sectioned roots could have influenced the degree of cleanliness. The buccal half of the split root canal segments was prepared for SEM investigation. The roots were coded and mixed so that the type of instrument used for preparation could not be identified during the SEM investigation.

Separate evaluations were undertaken for debris and smear layer with a five score system for each using the same set of reference photographs as in previous investigations (Hülsmann *et al.* 1997, 1998, 1999a, Hülsmann 2000, Hülsmann *et al.* 2001).

Debris was defined as dentine chips, pulp remnants and particles loosely attached to the root canal wall:

Score 1: Clean root canal wall, only few small debris particles

Score 2: Few small isles of debris

Score 3: Many accumulations of debris covering less than 50% of the root canal wall

Score 4: More than 50% of the root canal wall covered by debris

Score 5: Complete or nearly complete root canal wall covered by debris

Scoring of debris was performed using 200× magnification.

Smear layer was defined as proposed by the American Association of Endodontists' (1994) glossary *Contemporary*

Terminology for Endodontics: A surface film of debris retained on dentine or other surfaces after instrumentation with either rotary instruments or endodontic files; consists of dentine particles, remnants of vital or necrotic pulp tissue, bacterial components and retained irrigant.

Score 1: No smear layer, dentinal tubules open

Score 2: Small amount of smear layer, some dentinal tubules open

Score 3: Homogeneous smear layer covering the root canal wall, only few dentinal tubules open

Score 4: Complete root canal wall covered by a homogeneous smear layer, no open dentinal tubules

Score 5: Heavy, inhomogeneous smear layer covering the complete root canal wall.

Smear layer was scored under 1000× magnification.

After the central beam of the SEM had been directed to the centre of the object by the SEM-operator (F.S.) under 10× magnification, the magnification was increased to 200× and 1000×, respectively, and the canal wall region appearing on the screen was scored. The scoring procedure was performed by a second operator (M.H.) who could not identify the coded specimens nor the device used for root canal preparation. This operator had been trained in the scoring procedure, resulting in a sufficient intraobserver reproducibility (Hülsmann *et al.* 1997).

The incidence of procedural accidents was assessed during preparation of both the unsectioned and sectioned root canals. Apical patency was controlled using an ISO 10 reamer extending 1 mm beyond working length.

Statistical analysis

Statistical analysis was performed using the following tests: for straightening Wilcoxon's test was used ($P < 0.05$); for comparison of the cross-sections and root canal cleanliness Fisher's exact-test ($P < 0.05$) was taken. The Mann-Whitney test ($P < 0.05$) was used for comparison of working time.

Results

Distribution of preoperative root canal curvatures

The mean preoperative root canal curvature in the teeth of the Profile .04 group was 27.8° and in the Lightspeed group 28.4°.

Straightening

Due to three instrument fractures during preparation of the unsectioned roots, the number of specimens in this Profile .04 group was only 22. The mean straightening after preparation to size 45 in the Profile .04 group was 0.2° in the unsectioned and 0.3° in the sectioned roots (SD: 0–5°), in the Lightspeed group the mean straightening was 0.4° in the unsectioned and 0.2° in the sectioned roots (SD: 0–3°). The difference was not statistically significant (Table 1).

Cross-sections

The results concerning postoperative cross sections of the root canals are summarized in Table 2. Lightspeed produced slightly more irregular cross-sections in all parts of the root canal. Following the use of both Ni-Ti systems, the root canals in the majority of the cases showed round or oval root canal cross-sections and were rated acceptable. No statistically significant difference between the two systems occurred.

Superimposition of photographs of the cross-sections of the pre- and postoperative root canals showed that both systems left uninstrumented canal walls in many cases. Overall, 40 Lightspeed and 30 Profile .04 specimens out of 75 showed no contact between the pre- and postoperative root canal outlines, indicating sufficient circumferential instrumentation of the root canal wall. Following preparation with Lightspeed instruments, all parts of the root canals showed less

Table 1 Evaluation of root canal straightening (in °)

	Profile .04		Lightspeed	
	Unsectioned roots	Sectioned roots	Unsectioned roots	Sectioned roots
<i>n</i>	22*	25	25	25
Mean preoperative Curvature	27.8		28.4	
Min	0	0	0	0
Max	5	2	3	2
Median	0	0	0	0
Mean	0.21	0.28	0.38	0.24

*Due to three instrument fractures in this group, the number of root canals evaluated is only 22.

Table 2 Evaluation of postoperative cross-section

Section		Profile .04	Acceptable	Lightspeed	Acceptable
Coronal	Round	21		13	
	Oval	2	23	9	22
	Irregular	2		3	
Middle	Round	21		8	
	Oval	3	24	14	22
	Irregular	1		3	
Apical	Round	6		10	
	Oval	18	24	11	21
	Irregular	1		4	
		<i>n</i> = 75		<i>n</i> = 75	

Table 3 Contact between pre- and postoperative cross-section

Contact between pre- and postoperative cross-section	Profile .04				Lightspeed			
	Coronal	Middle	Apical	Total	Coronal	Middle	Apical	Total
>75%	0	0	1	1	0	0	1	1
>50%	0	1	1	2	0	0	0	0
>25%	2	1	4	7	3	2	3	8
0–25%	18	10	7	35	9	10	7	26
0%	5	13	12	30	13	13	14	40
<i>n</i>				75				75

Table 4 Assessment of root canal cleanliness

Score	Profile .04				Lightspeed			
	Coronal	Middle	Apical	Total	Coronal	Middle	Apical	Total
<i>Debris</i>								
1	3	5	1	9	7	2	2	11
2	11	8	5	24	12	15	13	40
3	7	7	9	23	6	6	8	20
4	1	2	6	9	0	2	2	4
5	0	0	1	1	0	0	0	0
<i>Smear layer</i>								
1	0	2	0	2	1	0	0	1
2	4	5	1	10	10	9	3	22
3	14	9	8	31	10	9	8	27
4	4	3	8	15	4	5	11	20
5	0	3	5	8	0	2	3	5
<i>n</i>				66*				75

*Due to three instrument fractures, nine specimens could not be evaluated in this group.

uninstrumented root canal walls than following preparation with ProFile instruments. Lightspeed instruments enlarged the root canal more uniformly with no specimen showing 50% or more contact between pre- and postoperative diameter (Table 3). The difference was statistically significant for the coronal third of the root canals ($P = 0.032$) with the Lightspeed system showing a superior performance. For the apical and the middle third no significant differences occurred.

Root canal cleanliness

Due to three instrument fractures, the number of specimens for the Profile .04 group was only 66 compared to 75 in the Lightspeed group. The results of the SEM analysis of the root canal walls concerning residual debris and smear layer are detailed in Table 4. Generally, the root canals showed no homogeneous appearance with only few specimens (Lightspeed: 14.7%, Profile .04: 13.6%) with completely clean walls without any remaining debris

(score 1) and a high number of scores 2 and 3 for both systems (Lightspeed: 80%, Profile .04 71.2%). Differences between the systems were not significant.

For smear layer Lightspeed preparation resulted in 65.3%, ProFile in 62.1% scored 2 and 3. No statistically significant differences occurred for the apical and middle thirds of the root canals. For the coronal region, Lightspeed cleaned significantly better ($P = 0.029$).

Procedural errors

Lightspeed preparation proved to be a safe technique with no instrument fracture, no perforation, no apical blockage, and no case of loss of working length. With the Profile .04 system three instrument fractures (one fracture with size 40, two fractures with size 35 instruments) occurred, but no perforation, no apical blockage, and no cases with loss of working length.

Working time

Working time, not including time for instrument changes and irrigation, measured during preparation of the unsectioned roots, resulted in a median of 123.4 s for Lightspeed instrumentation (20 instruments), and 94.3 s for the Profile .04 system (10 instruments). The difference was statistically significant ($P = 0.026$). The working time for each single instrument was shorter for Lightspeed than for ProFile. Including time for root canal irrigation, Lightspeed preparation resulted in a working time of 270.9 s (median) and Profile .04 instrumentation in a median working time of 190.1 s.

Discussion

In the majority of studies dealing with automated root canal preparation only two or three parameters of automated preparation are investigated. This study presents data on every aspect that is important for a definite conclusion on the clinical usefulness of a rotary device: root canal cleanliness, straightening of root canal curvature, working safety, and working time. Since this is part of a series of investigations on different rotary Ni–Ti instruments, a comparison of all major Ni–Ti systems will be possible. A similar series of investigations on rotary Ni–Ti systems has been undertaken previously (Thompson & Dummer 1997a,b,c,d, 1998a,b, 2000a,b, Bryant *et al.* 1998a,b) using simulated root canals in resin blocks with different kinds of curvatures that allowed standardization of the experimental model. In the present investigation root canal preparation was performed in extracted teeth.

Although the morphology of the root canals probably shows large variations, this seems to be the only way to evaluate the cleaning ability of a preparation technique, as in plastic blocks only canal blockage with resin debris may be studied.

Straightening of curved canals

Several studies, meanwhile, have confirmed the ability of rotary Ni–Ti files to maintain original root canal curvature even in severely curved canals (Glosson *et al.* 1995, Knowles *et al.* 1996, Short *et al.* 1997, Thompson & Dummer 1997a,b,c,d, 1998a,b, 2000a,b, Bryant *et al.* 1998a,b, Schäfer & Fritzenschaft 1999, Hülsmann 2000, Hülsmann *et al.* 2001).

The ability of Profile .04 instruments to prepare curved root canals has been reported in several studies. Schäfer & Fritzenschaft (1999) prepared simulated root canals with root canal curvatures of 28° and 35° with the Profile .04/.06 system and HERO 642 instruments. HERO 642 showed a better centring ability with only few minor deviations from the original curvature. Conversely, Frick *et al.* (1997), in root canals in extracted teeth with curvatures of 30° and more, could show no difference between ProFile and Quantec with only minimal straightening and a clear superiority compared to hand instrumentation, whereas Kosa *et al.* (1998) reported on more apical straightening with Quantec files compared to ProFile instruments. In the investigation of Thompson & Dummer (1997b) only minimal straightening of severely curved canals could be detected, the mean apical transportation was 0.01–0.016 mm.

The excellent maintenance of root canal curvature by Lightspeed preparation also has been reported by several studies (Glosson *et al.* 1995, Knowles *et al.* 1996, Tharuni *et al.* 1996, Barbakow & Lutz 1997, Thompson & Dummer 1997c,d, Shadid *et al.* 1998). Thompson & Dummer (1997d) described a mean apical transportation of 0.06 mm using Lightspeed instruments. The increased flexibility of the Ni–Ti files and the safety tips with rounded transition angles is discussed as the main factor for the superior shaping ability of both systems investigated in this study. Interestingly, the preparation technique – step-back for Lightspeed and step-down for ProFile – seems to have no measurable influence on the degree of straightening, whereas in studies on stainless steel instruments the step-down-techniques proved to be clearly superior in terms of apical cleanliness, apically extruded debris and straightening (Ruiz-Hubard *et al.* 1987, Murgel *et al.* 1991, Luiten *et al.* 1995, Al Omari & Dummer 1995).

The comparison of the pre- and postoperative photographs of root canal cross-sections enables the evaluation of the most important requirements of root canal preparation, that is, the prepared canal completely includes the original canal and no unprepared areas are left. Bramante *et al.* (1987) were the first to develop a method for the evaluation of changes in root canal diameter. Using a modification of their method, pre- and post-instrumentation photographs of the root canal diameter may be superimposed and deviations between the two root canal outlines can be measured.

The results for postoperative cross-sections in the present study did not differ significantly for both systems investigated, which is in accordance with the study of Short *et al.* (1997). Nevertheless, both systems were not able to prepare all parts of the root canal system and left areas of uninstrumented canal wall. Superimposition of photographs of the pre- and postinstrumentation cross-sectional form of the root canals showed that Lightspeed removed more dentine and left significantly less uninstrumented canal wall areas than Profile .04 in the coronal part of the root canal, whereas in the middle and apical parts of the root/canal no differences could be found. This probably is largely due to the use of size 70 Lightspeed instruments in the step-back phase of the preparation.

Cleaning ability

Most studies on Ni-Ti instrumentation in the last few years have focused on centring ability, maintenance of root canal curvature, or working safety of these new rotary systems; little information is available on their cleaning ability.

Peters *et al.* (1997) described a homogeneous smear layer in all parts of the root canal system after Lightspeed preparation without a chelating agent and with tap water as the only irrigant. Park *et al.* (1998) and Kochis *et al.* (1998) reported on similar results for Profile .04 as for hand instruments, both leaving uninstrumented canal wall areas, debris, and smear layer. In a comparative SEM study, Profile .04 and Lightspeed were equally effective in the debridement of root canals (Peters *et al.* 1998). The slightly superior cleaning ability of the Lightspeed system might be due to the fact that the number of irrigations with sodium hypochlorite was 12 for Lightspeed, but only 10 for Profile .04 and the larger size of Lightspeed instruments in the step-back phase.

Compared to results of a previous study, the cleaning ability of Profile .04 and Lightspeed was worse than for Quantec 2000 or HERO 642, for which frequently clean root canal walls without debris, no or minimal smear layer and many open dentinal tubules could be detected

under the SEM (Hülsmann *et al.* 2001). The main reason for the inferior cleaning ability of Lightspeed and Profile .04 may be the radial lands of the instruments which perform a planing action on the root canal walls rather than a cutting action that is claimed for Quantec 2000 and HERO 642. Medioni *et al.* (1999) confirmed the superior cleaning ability of Quantec 2000 when compared to HERO 642, Profile, and hand instrumentation.

Working safety

High numbers of instrument fractures have been reported for Ni-Ti files in several earlier studies (Barthel *et al.* 1998, Kavanagh & Lumley 1998, Schäfer & Fritzenschaft 1999, Baumann & Roth 1999), indicating that Ni-Ti instruments may be more susceptible to separation than conventional stainless steel instruments. In the study of Barthel *et al.* (1998) four fractures occurred during the preparation of 10 root canals with curvatures of more than 35°. Schäfer & Fritzenschaft (1999) had nine fractures in 24 simulated root canals with a 35° curvature. Baumann & Roth (1999) reported that the incidence of fractures of Profile .04 increased with increasing size of the files with most fractures occurring with size 30 and 35 files. Thompson & Dummer (1998a) reported on three fractures and three deformed instruments after preparation of 40 simulated root canals to size 35.

Knowles *et al.* (1996) could complete enlargement of 20 root canals with Lightspeed to size 50 and Short *et al.* (1997) completed 15 curved canals to size 40 without fractures. Tharuni *et al.* (1996) reported on one fracture during preparation of 12 simulated curved canals. In the evaluation of Thompson & Dummer (1997c) Lightspeed proved to be a safe system without any fracture or apical blockage but some cases of loss of working length, which in no case exceeded 1 mm. In a survey amongst Swiss clinicians 76% of the respondents had fractured an instrument at least once. The main reasons for such fractures were non-constant speed of rotation, excessively high rotational speed, overuse of instruments, and too much pressure (Barbakow & Lutz 1997). As advocated by Gambarini (2000), the use of a newly developed low-torque endodontic motor with constant speed for Ni-Ti preparation with individually adjusted torque levels for each file of any Ni-Ti system instead of a high-torque motor might help to reduce the risk of instrument separation. Further studies could show that the frequency of instrument fractures may be related to the operator's experience with a certain system (Glosson *et al.* 1995, Pruett *et al.* 1997, Barbakow & Lutz 1997, Baumann & Roth 1999).

The results of the present study are in general agreement with the results of the studies performed by Thompson & Dummer (1997a,b,c,d) in simulated root canals with different types of curvature. They described a very low incidence of procedural errors such as fractures, apical blockages, elbows, zips, or loss of working length for Lightspeed, as well as for Profile .04.

Working time

The finding that ProFile instrumentation took significantly less time than Lightspeed preparation, to a large extent, will be due to the fact that the number of instruments for both systems differs (Lightspeed: 20, ProFile: 10). Following the protocol of this study the number of irrigations for ProFile was 10, for Lightspeed 12. Clinically, the difference will be even more evident as time for instrument changes and adjustment of the stopper systems has to be added. On the other hand, the preparation time for each single instrument was shorter for Lightspeed, due to the reduced contact zone between instrument and root canal wall. Conversely, Thompson & Dummer (1997a,b,c,d), in their studies on simulated root canals with different kinds of curvatures, could find nearly equal preparation times for Lightspeed and Profile .04, but when using Profile .04 with ISO-sized tips the working time was shortened substantially (Bryant *et al.* 1998a). These differences might be explained by the fact that the time an operator keeps the instrument working inside the root canal and the speed for the up and down movement of the files is not clearly defined and will vary individually. The total time for preparation for both systems was clearly shorter in the present investigation than in the studies mentioned above, as time for instrument change, stopper adjustment and irrigation were not included.

Overall, the ability of Ni-Ti systems to shorten preparation time compared to hand instrumentation or to automated root canal preparation using different endodontic handpieces with conventional stainless steel files has been confirmed already in a number of previous studies (Esposito & Cunningham 1995, Glosson *et al.* 1995, Hülsmann 2000, Hülsmann *et al.* 2001).

Conclusions

The results of the present study confirm the results of previous studies on rotary nickel-titanium systems concerning maintenance of root canal curvature and centring ability of such instruments. Both systems showed some deficiencies in terms of debridement, leaving debris and smear layer. No significant differences between

Profile .04 and Lightspeed could be found, except for working time, with ProFile preparing significantly faster. Lightspeed and Profile .04 may be recommended for clinical use.

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